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MEASUREMENTS OF LONG-LIVED COSMOGENIC NUCLIDES IN RETURNED COMET NUCLEUS SAMPLES

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Measurements of long lived cosmic ray produced radionuclides have given much information on the histories and rates of surface evolution for meteorites, the moon and the earth [e.g. 1]. These nuclides can be equally useful in studying cometary histories and post nebular processing of cometary surfaces. The concentration of these nuclides depends on the orbit of the comet (cosmic ray intensity changes with distance from the sun), the depth of the sampling site in the comet surface, and the rate of continuous evolution of the surface (erosion rate of surface materials). If the orbital parameters and the sampling depth are known, production rates of cosmogenic nuclides can be fairly accurately calculated by theoretical models [2] normalized to measurements on lunar surface materials and meteoritic samples. Due to the continuous evaporation of surface materials, we expect the long lived radioactivities to be undersaturated. Accurate measurements of the degree of undersaturation in in nuclides of different half-lives allow us to determine the rate of surface material loss over the last few million years.

Solar cosmic ray (SCR) production in the surface layer can give the most precise information about the rates of evaporation and dust evolution in the sampled region. While many comets spend very little time within the region of the solar system where SCR effects are significant, a short period comet should have a higher measurable component of these nuclides in near-surface layers. The mission target will of course be a short-period comet. We can make detailed estimates when this comet is selected.

One must pay attention to the nature of the region where the samples are taken. If it is an active region of gas and dust emission, the SCR effect will be removed once each orbit near perihelion. If it is an inactive region, the SCR products can accumulate throughout the comet's lifetime as a short-period object. This offers us the opportunity to date the orbital perturbation which brought the comet into the present short-period regime.

The nuclides which we propose to measure are ^{10}Be (half-life = 1.5 My), ^{26}Al (0.7 My), ^{36}Cl (0.30 My), ^{41}Ca (0.1 My), and ^{53}Mn (3.7 My). All nuclides should be measured in silicate separates, i.e. dust particles, and ^{10}Be should also be measured in ice and in carbon separately. We have measured these nuclides (except ^{41}Ca) in less than 1 mg of deep sea particles and in lunar rocklets using AMS (Accelerator Mass Spectrometry) and neutron activation (^{53}Mn) [e.g. 3,4]. The present detection limit of AMS is on the order of 10^6 atoms or less. A few to 10 mg of silicate separate would enable us to measure all five nuclides proposed with less than 10 % error. These measurements could be performed today, using existing technology, except for ^{41}Ca which is being studied and is expected to be measurable at these levels within a year. A very useful set of samples would consist of a surface sample (0-a few cm depth) and a series of core samples at depths down to 1 m, ideally 10 samples at intervals of 10 cm. Alternatively a large diameter short core to 20 cm depth would enable us to give better resolution to surface processes. A surface sample of a few mg ice and a few mg carbon is needed for the additional ^{10}Be measurements. It is extremely important that the depths below cometary surface be known for all samples.

The depth profile of activity in the top 100 g/cm^2 (or more) offers another interesting possibility: to determine production rates and hence the cosmic-ray flux outside the sun's magnetosphere. Because the sun's magnetic field removes many lower-energy galactic cosmic ray (GCR) particles, production rates due to GCR irradiation are usually low at the surface and increase with depth. Beyond the magnetosphere the lower energy particles would raise the production at the surface and the measured profiles should be qualitatively different. The results should be very interesting for cosmic-ray physics.

Short half-lived nuclides such as ^{7}Be, ^{22}Na, ^{54}Mn, and ^{60}Co are less favorable for this work because of the long transportation time of the sample return. The radioactivity produced in the comet would decay appreciably during the transportation and measurable amounts of the nuclides would be produced by cosmic ray bombardment in the space probe unless the sample is encased in massive shielding. In addition, the high detection limit due to direct decay counting of these short lived nuclides requires larger sample sizes for the same precision. In-situ measurements of such nuclides should be considered.

References

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